

Single-Spin Asymmetries at CLAS

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(for the CLAS collaboration)

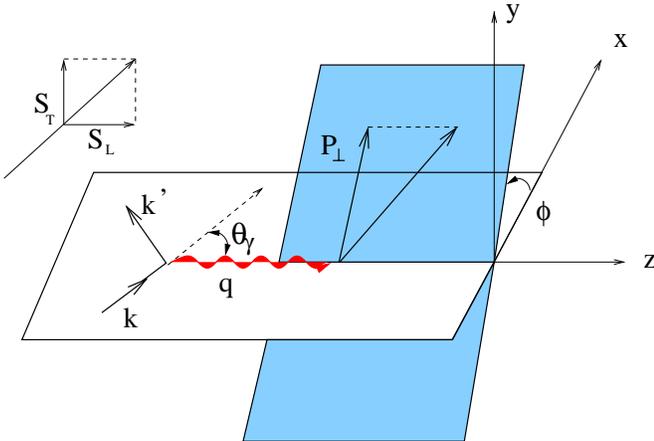
SPIN 2002

- Physics goals
- The Experiment
- Target SSA
- Beam SSA
- Summary & Outlook

Polarized Semi-Inclusive DIS

Main goal:

- Detect final state e' and π^+ in $\vec{e}\vec{p} \rightarrow e'\pi^+ + X$
- Measure single beam and target SSA.
- Extract information on underlying distribution and fragmentation functions.



$$\begin{aligned}
 Q^2 &= 4EE' \sin^2\left(\frac{\theta}{2}\right) \\
 \nu &= E - E' \\
 x &= \frac{Q^2}{2m\nu} \\
 y &= \frac{\nu}{E} = \frac{p \cdot q}{p \cdot k} \\
 z &= \frac{E_h}{E} \\
 \sin \theta_\gamma &\approx \frac{2Mx}{Q} \sqrt{1-y}
 \end{aligned}$$

Measured SSA in DIS (HERMES, SMC):

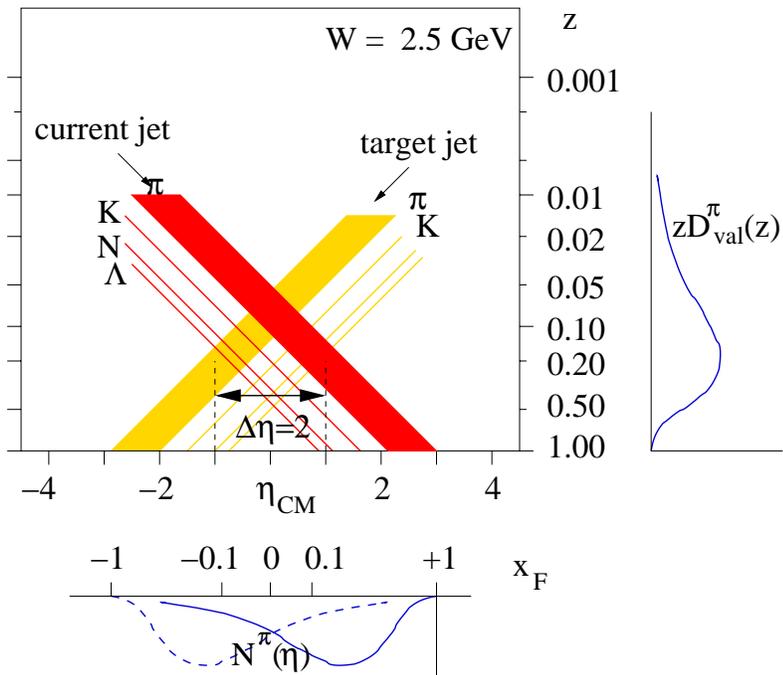
- Significant target SSA in $e\vec{p} \rightarrow e'\pi^+ + X$

Major sources of SSA:

- T-odd fragmentation functions (Collins effect)
- T-odd distribution functions (Sivers effect)

CLAS at 4-6 GeV

$$ep \rightarrow e'h + X$$



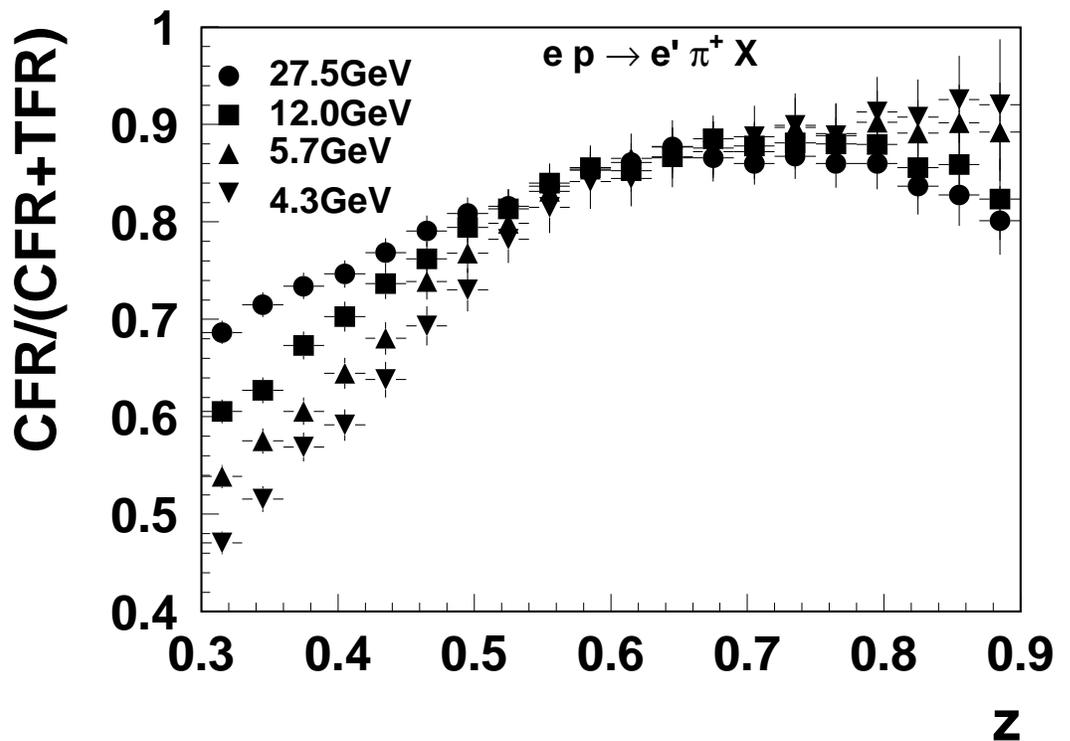
At 4-6 GeV (LUND-MC) the current fragmentations could be separated with $x_F > 0.1$ and $z > 0.5$.

DIS:

$$Q^2 > 1$$

$$W^2 > 4$$

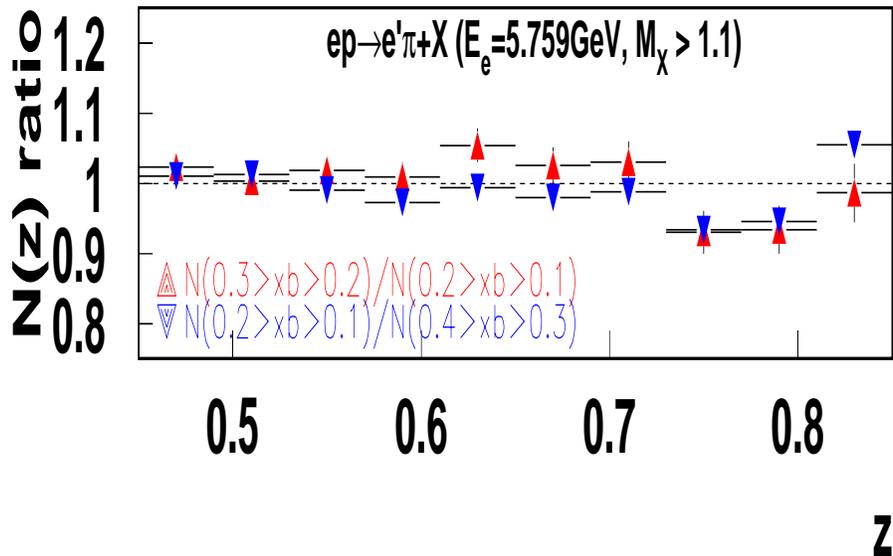
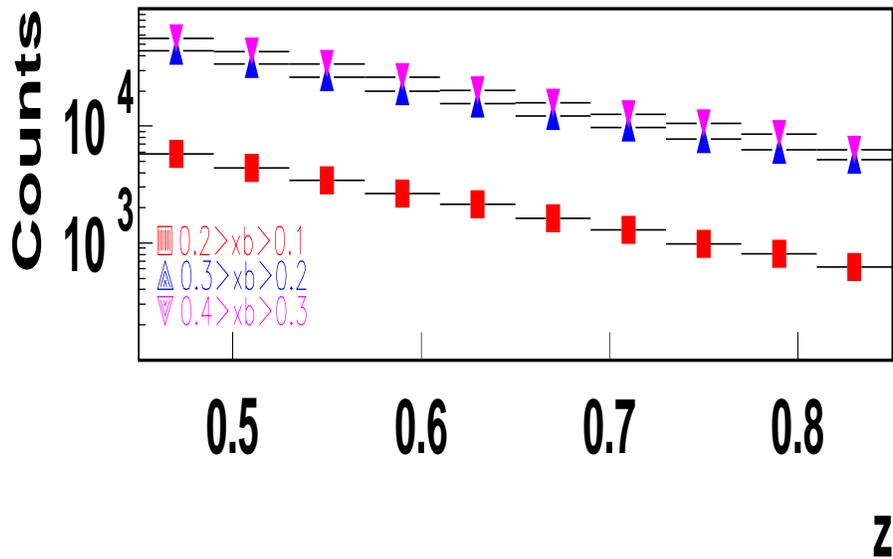
$$y < 0.85$$



The separation is CFR with $0.8 > z > 0.5$ is not changing significantly with beam energy.

x, z Factorization

$ep \rightarrow e'\pi^+ + X$ at 5.7 GeV (CLAS E1 experiment).



The z distribution for different ranges of Bjorken x .

No significant variation observed in z dependence for different x ranges.

Contributions to σ in $ep \rightarrow e'\pi + X$

The σ for longitudinally polarized leptons scattering off unpolarized protons:

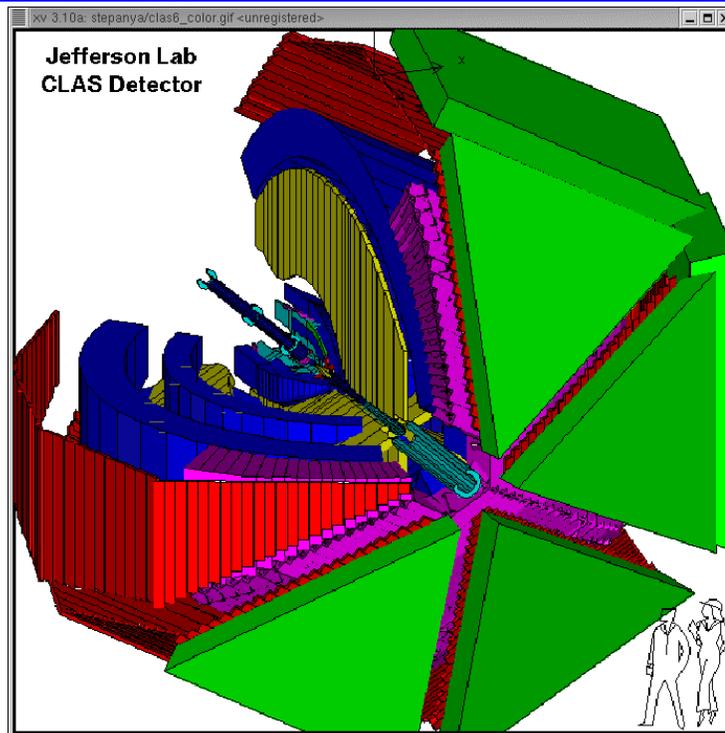
$$\begin{aligned} \frac{d\sigma_{UU}}{dx_B dy dz d^2 P_\perp} &= \frac{4\pi \alpha^2 s}{Q^4} x_B \left\{ \left(1 - y + \frac{1}{2} y^2 \right) \mathcal{H}_T \right. \\ &\quad + (1 - y) \mathcal{H}_L \\ &\quad - (2 - y) \sqrt{1 - y} \cos \phi \mathcal{H}_{LT} \\ &\quad \left. + (1 - y) \cos 2\phi \mathcal{H}_{TT} \right\}, \end{aligned}$$

$$\frac{d\sigma_{LU}}{dx_B dy dz d^2 P_\perp} = \lambda_e \frac{4\pi \alpha^2 s}{Q^4} x_B y \sqrt{1 - y} \sin \phi \mathcal{H}'_{LT}$$

Different structure functions could be extracted as azimuthal moments of the total cross section.

$$\frac{1}{2} A_{LU}^{\sin \phi} = \langle \sin \phi \rangle = \frac{1}{P^\pm N^\pm} \sum_{i=1}^{N^\pm} \sin \phi_i. \quad (1)$$

CLAS EG1/E1 experiments

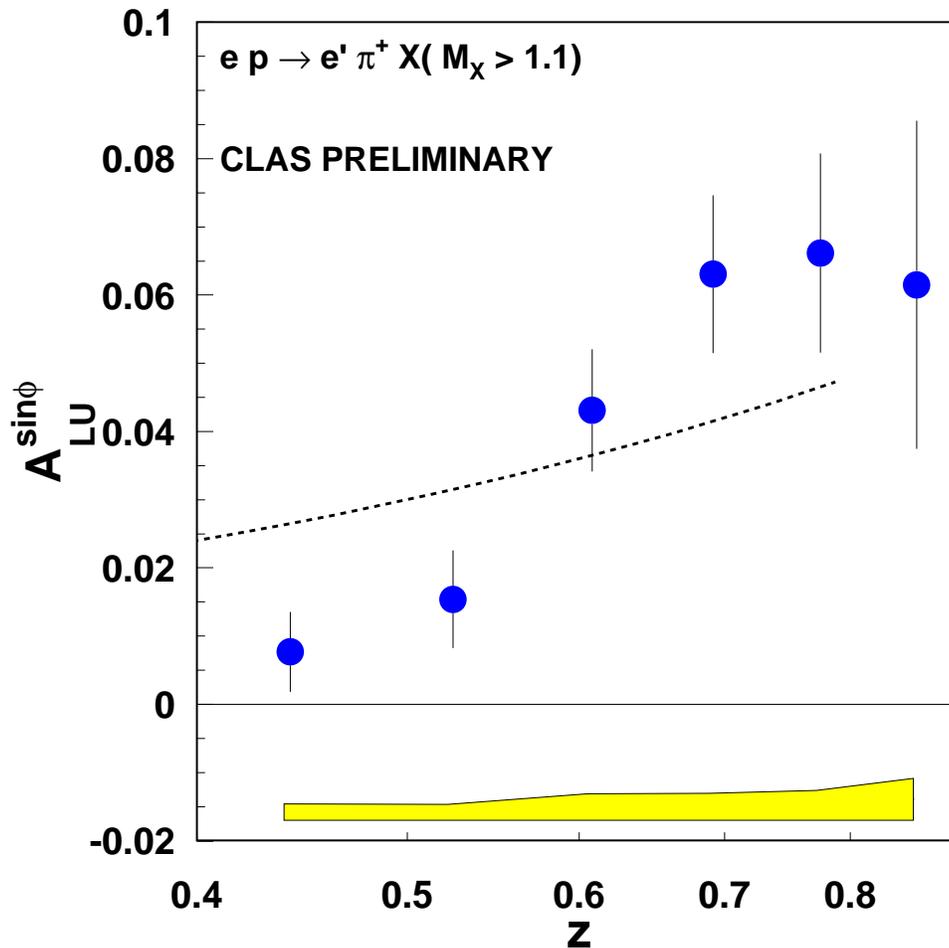


Target	hydrogen, NH_3
Beam Energy	4.3 GeV
Beam Polarization	0.65 ± 0.05 (longitudinal)
Target Polarization	0.5 ± 0.05 (longitudinal)
Acceptance in e_θ	$20 < \theta < 50 < e_\theta > = 32^\circ$
Acceptance in π_θ	$8 < \theta < 65 < \pi_\theta > = 23^\circ$
DIS cuts	$Q^2 > 1$ hard scattering $W^2 > 4$ small res. contribution $y < 0.85$ small rad. effects
Cuts on π^+	$0.5 < z < 0.8$ current fragment. $M_X > 1.1$ exclude exclusive ev. $0.02 < P_\perp < 1.1$, ϕ well defined
$\gamma^* p \rightarrow \pi^+ + X$	400K rec. events in e1c 2.7M rec. events in eg1

~ factor of 10 more 5.7 GeV data available both for polarized and unpolarized targets.

Beam SSA: $\sin \phi$ moment

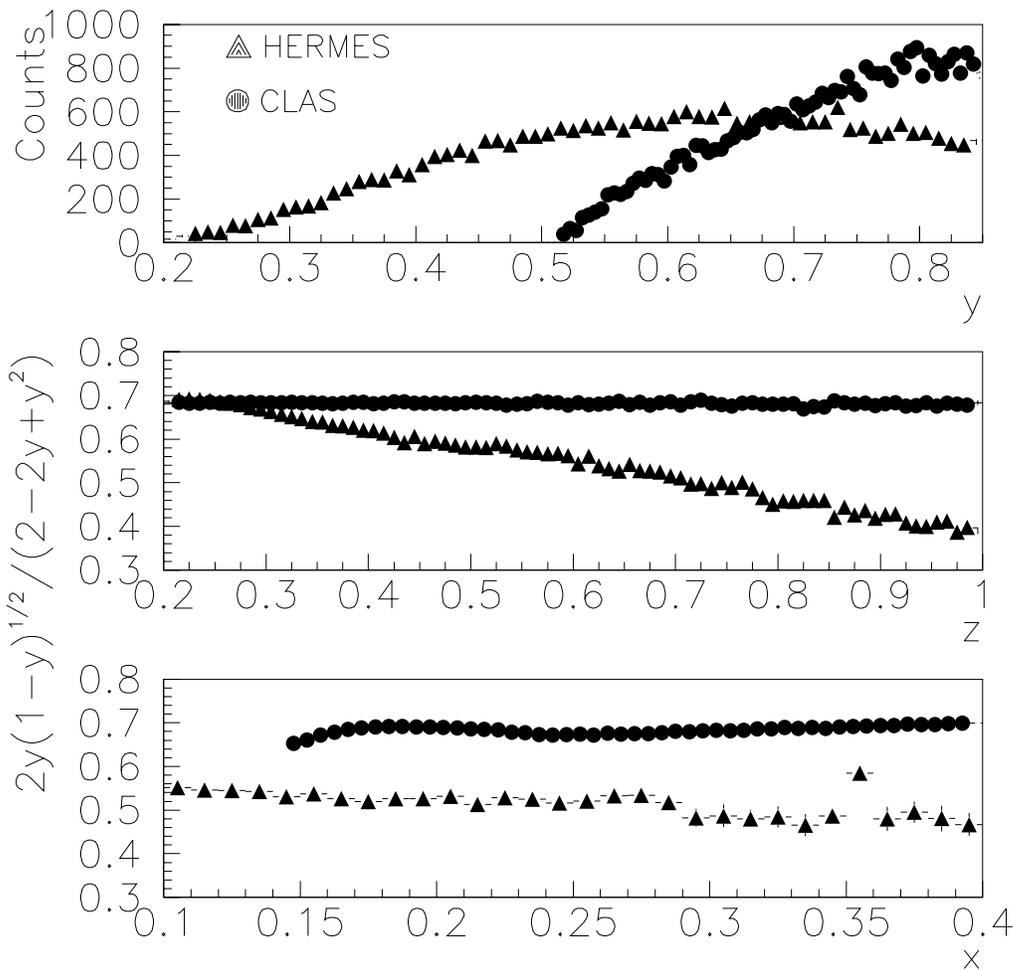
$$A_{LU}^{\pi^+} \propto \lambda_e F(y) \frac{\mathcal{H}_{LT'}}{\mathcal{H}_T} \propto \lambda_e \frac{H_1^{u,\pi^+}(z)}{D_1^{u,\pi^+}(z)}$$



The z dependence of A_{LU} (CLAS e1c 4.3GeV data), may provide information on the “Collins” function. The dashed line is a fit to Collins function $H_1^{u,\pi^+}(z)$ from HERMES A_{UL} data.

Main contribution to systematic error from acceptance and beam polarization.

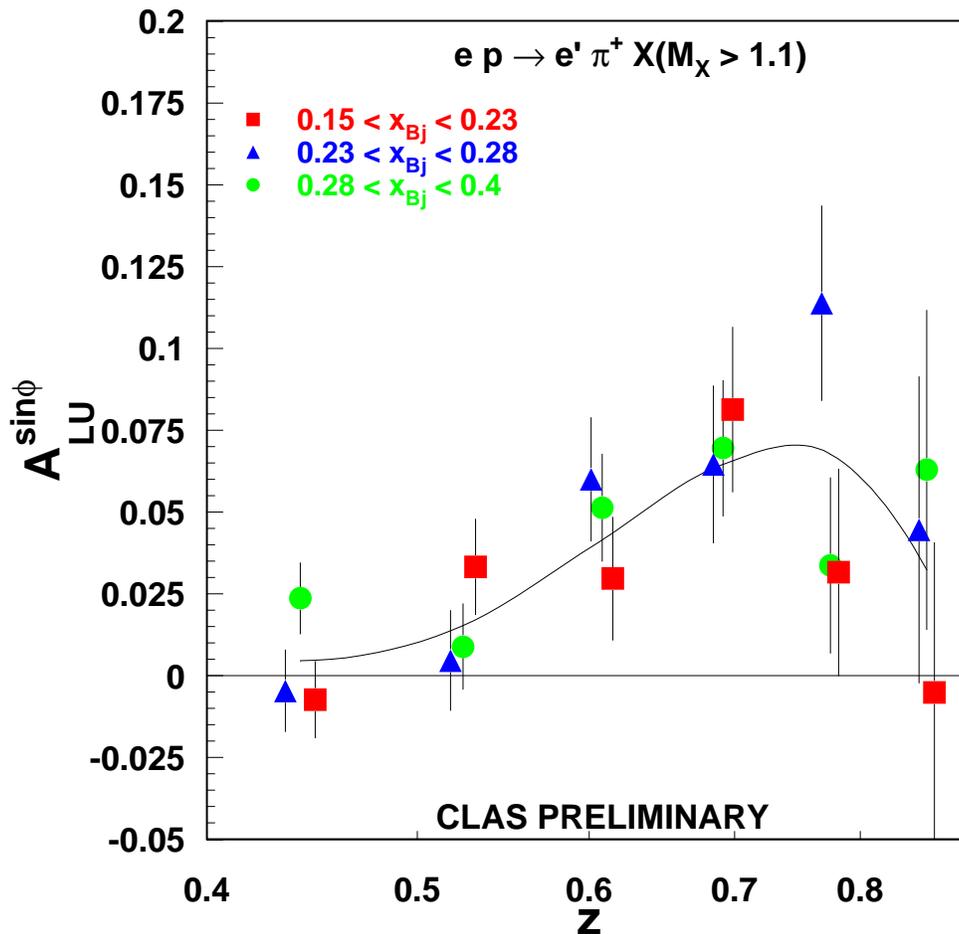
Kinematics: A_{LU} vs y



The $\sin \phi$ moment as a function of y .

For CLAS kinematic factor doesn't depend on z and x

Factorizing $A_{LU}(z)$



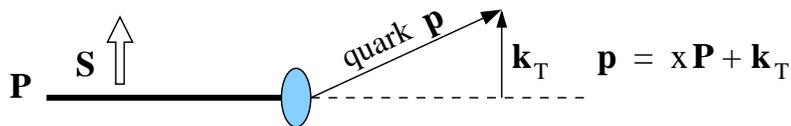
The beam SSA as a function of z for different ranges of Bjorken x from e1c 4.25GeV data.

Beam SSA shows no significant variation of z dependence for different x .

Classification of distribution functions:

SSA originates from multi-parton correlation and intrinsic quark transverse momentum k_T .

Partons carry a fraction x of proton's longitudinal momentum P and transverse component k_T



Distribution functions from Mulders & Co.

distribution functions		chirality	
		even	odd
twist 2	U	\mathbf{f}_1	h_1^\perp
	L	\mathbf{g}_{1L}	h_{1L}^\perp
	T	f_{1T}^\perp, g_{1T}	$\mathbf{h}_1 \quad h_{1T}^\perp$
twist 3	U	f^\perp	\mathbf{e}
	L	g_L^\perp	\mathbf{h}_L
	T	$\mathbf{g}_T \quad g_T^\perp$	$h_T \quad h_T^\perp$

$$f_1(x) \equiv \int d^2 k_T f_1(x, k_T).$$

$$h_{1L}^{\perp(1)}(x) \equiv \int d^2 k_T \left(\frac{k_T^2}{2M_h^2} \right) h_{1L}^\perp(x, k_T).$$

Contributions to σ in polarized SIDIS

$$\sigma_{UU} \propto (1 - y + y^2/2) \sum_{a, \bar{a}} e_a^2 x f_1^a(x) D_1^a(z)$$

$$\sigma_{LL} \propto \lambda_e S_L y (2 - y) \sum_{a, \bar{a}} e_a^2 x g_1^a(x) D_1^a(z)$$

$$\sigma_{UT}^{\sin \phi} \propto S_T (1 - y) \sin \phi_C \sum_{a, \bar{a}} e_a^2 x h_1^a(x) H_1^{\perp a}(z)$$

$$\sigma_{UT}^{\sin \phi} \propto S_T (1 - y) \sin \phi'_C \sum_{a, \bar{a}} e_a^2 x f_{1T}^\perp(x) D_1^a(z)$$

$$\sigma_{UL}^{\sin \phi} \propto S_L \sin \phi (2 - y) \sqrt{1 - y} \frac{M}{Q} \sum_{a, \bar{a}} e_a^2 x^2 h_L^a(x) H_1^{\perp a}(z)$$

$$\sigma_{LU}^{\sin \phi} \propto \lambda_e \sin \phi y \sqrt{1 - y} \frac{M}{Q} \sum_{a, \bar{a}} e_a^2 x^2 e^a(x) H_1^{\perp a}(z)$$

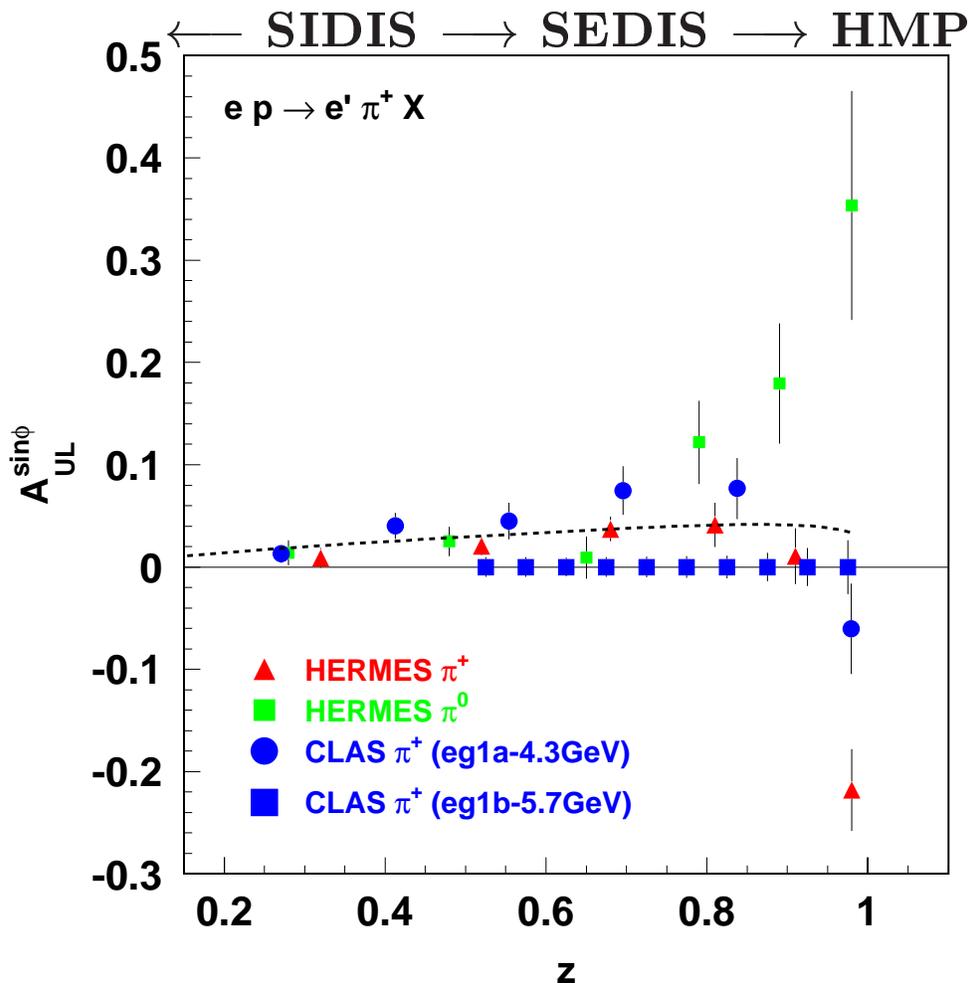
- λ_e, S_L, S_T electron and proton long. and trans. pol.
- $\sum_{a, \bar{a}}$ \rightarrow sum over quarks and anti-quarks.

D_1, H^\perp unpolarized and polarized ("Collins") fragmentation functions.

Physics mechanisms to generate non-zero T-odd functions discussed by Collins 1993, Bacchetta et al. 2002 (H_1^\perp) and Brodsky et al., Ji et al 2002 (f_{1T}^\perp)

LPol Target SSA for π^+

$$A_{UL} \propto \frac{H_1^u(z)}{D_1^u(z)} \text{ or } \frac{f_{1T}^{\perp u}(x)}{u(x)} \quad (\text{Brodsky et al., Ji et al. 2002})$$

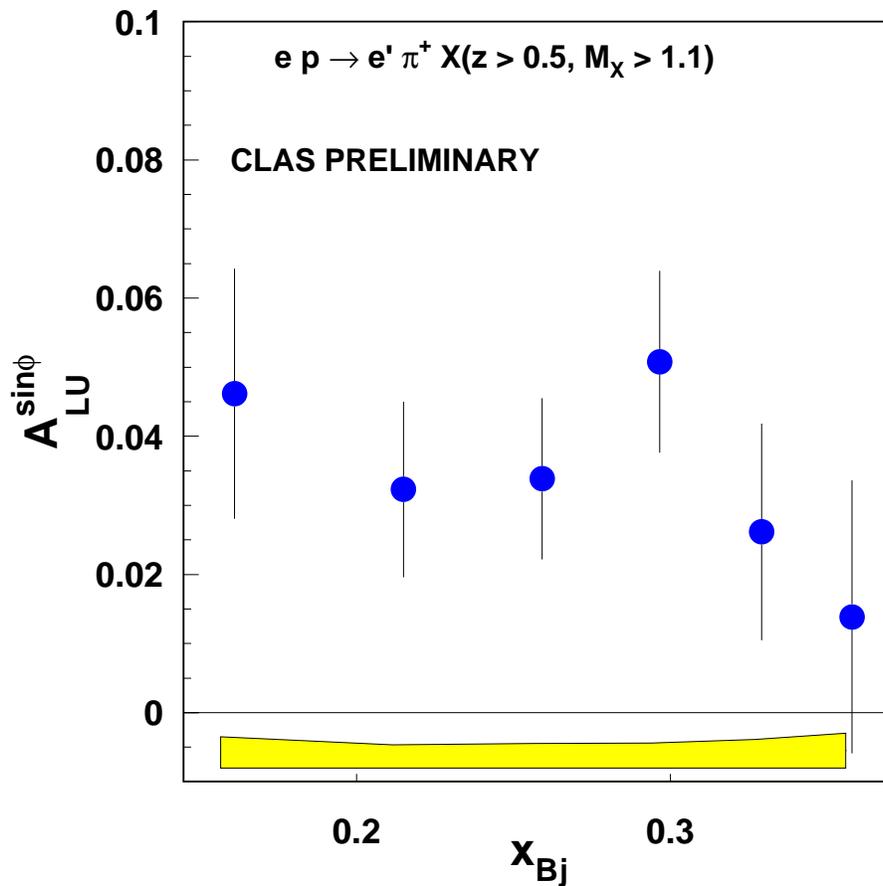


The z -dependence of target SSA from CLAS is consistent with HERMES measurement.

A_{UL} both in magnitude and sign in agreement also with predictions based on Siverson mechanism.

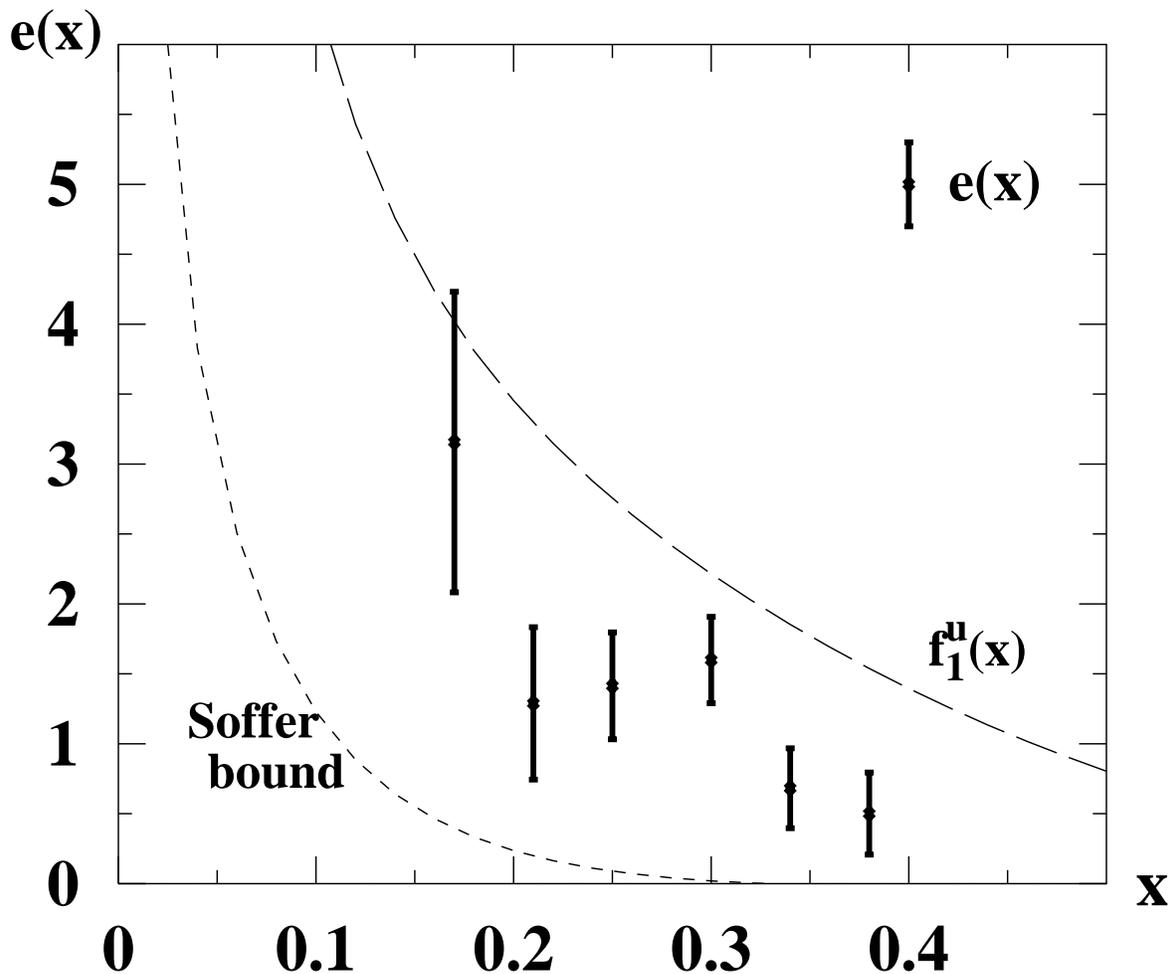
Beam SSA: $\sin \phi$ moment

$$A_{LU}^{\pi^+} \propto \lambda_e \frac{e^u(x)}{u(x)}$$



The relatively flat x dependence of A_{LU} (CLAS e1c 4.3GeV data) is consistent with bag model calculations of the twist-3 distribution function $e(x)$ (Signal NP B 497 1997).

First extraction of $e(x)$ from CLAS data



Twist-3 $e(x)$ extraction (Efremov et al.) from CLAS A_{LU} measurement ($\mathcal{H}'_{LT} \approx e(x)H_1^\perp(z)$).

Upper and lower curves are for $f(x)$ and lower bound for $e(x)$ given by the Soffer inequality ($e(x) > 2g_T - h_L$).

Summary and Outlook

- Significant beam and target single-spin asymmetries observed at CLAS in single-pion production in polarized electron scattering off the unpolarized and longitudinally polarized protons.
- Significant single-beam spin asymmetry measured for the first time in π^+ electroproduction in DIS.
- Significant difference observed in the z-dependence of target and beam single-spin asymmetries in DIS.
- Sign and magnitude of CLAS target SSA are in qualitative agreement with published data (HERMES 1999-2000).
- Measure beam and target SSA and their ratio in DIS region from CLAS eg1b(polarized NH_3) and e1-6 (unpolarized hydrogen) experiments with higher energy ($E_e = 5.7 GeV$) and much higher statistics (3billion triggers).
 - extraction of beam and target SSA for other hadrons ($\pi^0, \pi^-, \rho...$).
 - extraction of Q^2 dependency of beam and target SSA for fixed x
- Transversely polarized target in simulation stage.